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A study on the surface roughness of a thin HSQ coating on a fine milled surface

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Abstract

The paper discusses a novel application of a thin layer coating on a metallic machined surface with particular attention to roughness of the coating compared to the original surface before coating. The coating is a nominally 1 µm film of Hydrogen Silsesquioxane (HSQ) which is commonly used in the semiconductor industry in the manufacture of integrated circuits. The work piece is a fine peripheral-milled tool steel surface which is widely used in industrial applications. Roughness improvement after the application of HSQ coating is reported.

1 Introduction

Polishing of metal tools using abrasives is the traditional way to obtain a smooth surface for industrial applications. Applying HSQ coating on the surface might be regarded as a replacement for polishing with abrasives. Thin film Hydrogen Silsesquioxane (HSQ) is commonly used in the semiconductor industry in the manufacture of integrated circuits (ICs), both as a low-k dielectric and as a planarization material to fill in the gaps between metal wires and spatially separated components [1]. HSQ is an unstable, cage-like silane hydrolyzate, which cures to form a solid, amorphous quartz layer. It can be obtained as a pure material or in liquid form prepared for IC manufacture, which can be applied via typical means of coating, leading normally to reductions in the surface roughness [2]. The thickness measurement and overall roughness measurement of HSQ coating was presented by authors [3]. The current work focuses on characterisation of the thin HSQ coating applied on a flat surface of steel with particular attention to roughness improvement of an exactly defined area on a machined surface before and after coating application.

2 Measurements and visualisation of coating roughness

The work piece is a 60 mm × 40 mm plate made of Uddeholm IMPAX Supreme which was manufactured by peripheral milling with a roughness of 0.4 µm R_a (3.5 µm R_z). A squared area approx. 100 µm × 100 µm was registered using micro-indentations. The size of indentations was 15 µm × 15µm with a depth of about 2 µm. Indentations were designed with respect to the size of milling asperities and coating thickness (nominally 1 µm) so they were clearly visible after the coating. An area of 35 µm × 35 µm containing three edges of a square-shaped indentation was defined as the interest zone (figure 1). The interest zone was scanned by AFM with a sampling distance of 50 nm (in line with AFM movement) and distance between each 2D scan was 100 nm. After the measurement the work piece was entirely coated. Then the same interest zone was found again with the help of making alignment around the edges of the same indentation. Final series of AFM measurements on the interest zone provided the advantage of accurately investigating the minute surface changes in individual registered cross sections within the 35 µm × 35 µm area. The fine surface of the HSQ coating compared to rough surface of the substrate is evident through visualisation of 3D scans as shown in the figure 1.

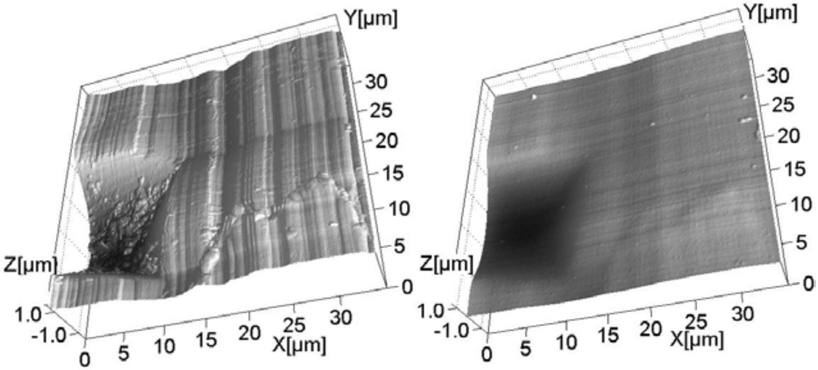

Figure 1. AFM micro scans (35 µm × 35 µm) of a fine milled surface before coating (left) and after application of HSQ coating (right)

Figure 2 depicts location of three pairs of cross sections (A, B and C) after superposition of the 3D scans before and after coating. The profiles shown are unfiltered. In each pair the lower profiles belong to the machining surface and the upper profiles show the coating surface. These graphs are measured from individual surfaces and matched to show the surface roughness improvement, so the height difference between them is not calibrated for coating thickness measurements.

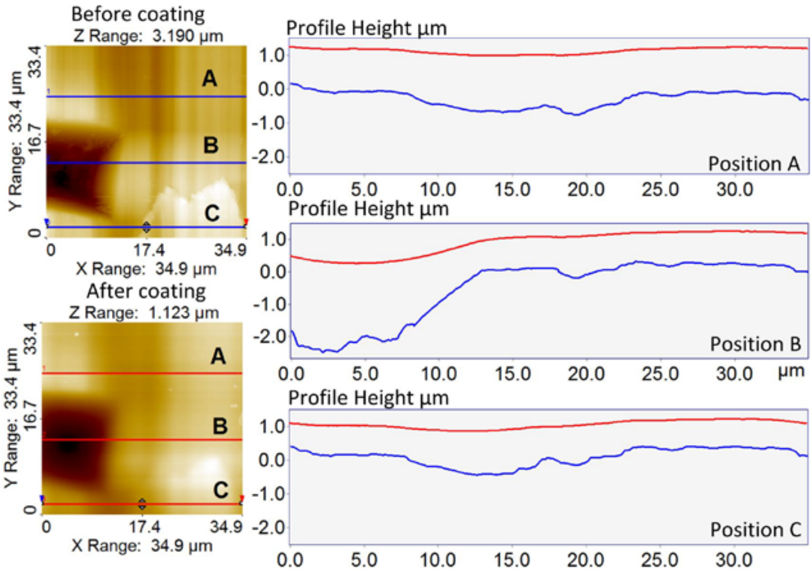

Figure 2. Cross sections A, B and C of AFM micro scans and relevant profiles; upper profile: coated; lower profile: machined

3 Quantification of roughness improvement

It is not likely to use roughness parameters in scan length of 35 µm, because there are limitations to use conditions to apply standard filters [4], therefore the quantification was done using height histogram and void volume. Figure 3 shows height histogram of the 3D AFM data which is the statistical distribution of heights of the topographical images. The histogram shows that the initial height difference before coating is 3.189 µm and it is reduced to 1.222 µm showing 62 % reduction. Another relevant way of quantification is by calculating the void volume. Void volume is the volume between the two height levels (dashed lines in figure 3 - right) crossing the pixels with highest and lowest z-values. The void volume of the 3D scan before coating is 1086.1 µm^3 while the coated surface has a volume of 400.66 µm^3. This shows that the void volume has reduced by 63 %.

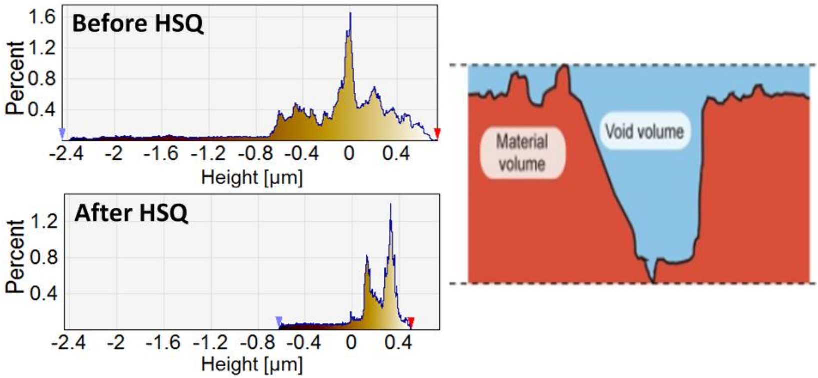

Figure 3. left: Height histogram of 3D AFM scans before and after HSQ coating; right: definition of void volume as a surface quantification parameter

4 Conclusion

An area of 35 µm x 35 µm was registered carefully on the surface of a flat milled tool steel and was scanned with AFM. After applying a nominal 1 µm layer of HSQ coating the location was found again and scanned with AFM. Coming back to the same location, it was possible to report the surface improvement in a definitive way. 3D and 2D surface visualizations of the same cross sections before and after coating are demonstrated. The height distribution and void volume show more than 60 % reduction after coating which states the roughness improvement due to HSQ coating.

Acknowledgment

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